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Decay Losses Associated With Wounds in Commercially Thinned True Fir Stands in Northern California

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Abstract

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A total of 562 white firs (*Abies concolor* (Gord. & Glend.) Lindl. ex Hildebr.) and red firs (*A. magnifica* A. Murr.) with logging wounds were felled, dissected, and analyzed for infection and decay in 28 commercially thinned stands on the Klamath and Tahoe National Forests in California. On the Klamath National Forest, decay losses associated with wounds were 1.2 and 5.7 percent of the gross merchantable cubic-foot volume and Scribner board-foot volume, respectively; on the Tahoe National Forest, these volumes were 1.7 and 7.6 percent. Wound area and age were most closely related to extent of decay. Volumes are given in cubic and board feet of decay for wounds of various sizes and ages.

Keywoods: Heartrot, logging damage, thinning, white fir, red fir.

Summary

In 1981, 562 white and red firs with wounds were sampled in 28 commercially thinned stands in the Klamath and Tahoe National Forests in northern California. All stands were naturally established and had been thinned by conventional logging methods 2 to 25 years before the study was conducted. Trees were selected primarily near skid trails because most logging damage was concentrated there.

Thirty-six trees had wounds that occurred many years before the sample stands were thinned. Decay losses associated with these wounds were 3.1 and 7.1 percent of the cubic- and Scribner board-foot volumes, respectively, of the affected white and red fir trees. In the Klamath National Forest, 258 true firs with 269 thinning wounds were sampled. Volume losses associated with decay were 1.2 and 5.7 percent, respectively, of the gross merchantable cubic- and Scribner board-foot volumes. In the Tahoe National Forest, 268 true firs with 271 thinning wounds were sampled. Decay associated with wounds on both Forests ranged from 0 to 19.4 and 0.1 to 47.0 percent, respectively, of the gross merchantable cubic- and Scribner board-foot volumes.

Neither wound aspect nor condition (open or closed) significantly influenced incidence of infection or amount of associated decay in true firs in either Forest. Wound height, however, had a significant effect on extent of decay in both Forests. The most important wound characteristics related to associated decay were age and original and present size. Present wound size and age were used in regression analysis to develop equations that can be used to estimate cubic- and Scribner board-foot decay losses associated with thinning wounds on true firs in the Klamath and Tahoe National Forests.

Contents

Introduction

True firs (*Abies concolor* (Gord. & Glend.) Lindl. ex Hildebr. and *A. magnifica* A. Murr.) form extensive young-growth stands in northern California. Commercial thinning is increasingly important as a silvicultural treatment to improve vigor and productivity in these stands. Stand entries with logging equipment often result in wounding of some of the reserve trees. Thin-barked true firs are highly susceptible to logging damage, and because they lack resin ducts, injuries are frequently invaded by decay fungi. Plant pathologists and forest managers are concerned that decay associated with wounds may significantly offset the benefits expected from thinning.

In several thinned true fir stands in northern California, Maloy (1979) noted that serious decay losses were associated with logging wounds, especially those on the lower bole. This observation led to a series of studies by Aho and others (1983b) in true fir stands on the Lassen National Forest to quantify the amount of logging damage to residual trees and associated decay losses; they found that 22 to 50 percent of the crop trees in conventionally thinned stands had logging damage. Dissection of trees with wounds averaging 13 years of age revealed that decay losses were 1.9 and 4.5 percent of the gross merchantable cubic-foot volume of red and white fir, respectively, and 6.8 and 14.5 percent of the board-foot volume. Significant losses found in the Lassen study raised the question of whether similar losses were also occurring on other National Forests. The objectives of this study were (1) to determine the incidence of infection and decay volumes associated with logging wounds in thinned, young-growth true firs stands in the Klamath and Tahoe National Forests in northern California; and (2) to determine relations between certain wound characteristics (age, size, height, condition, and aspect) and incidence of infection and amount of associated decay.

Methods

Stand and Tree Selection

In 1981, white and red firs with wounds were sampled in 28 commercially thinned stands in the Klamath and Tahoe National Forests (fig. 1). All stands were naturally established and had been thinned by conventional logging methods 2 to 25 years before the study was conducted. Randomization of stand selection was not possible because of the relatively small number of stands thinned in the past on these Forests. Therefore, it was necessary to include in our sample almost all available stands, especially those logged more than 5 years before the study was conducted.

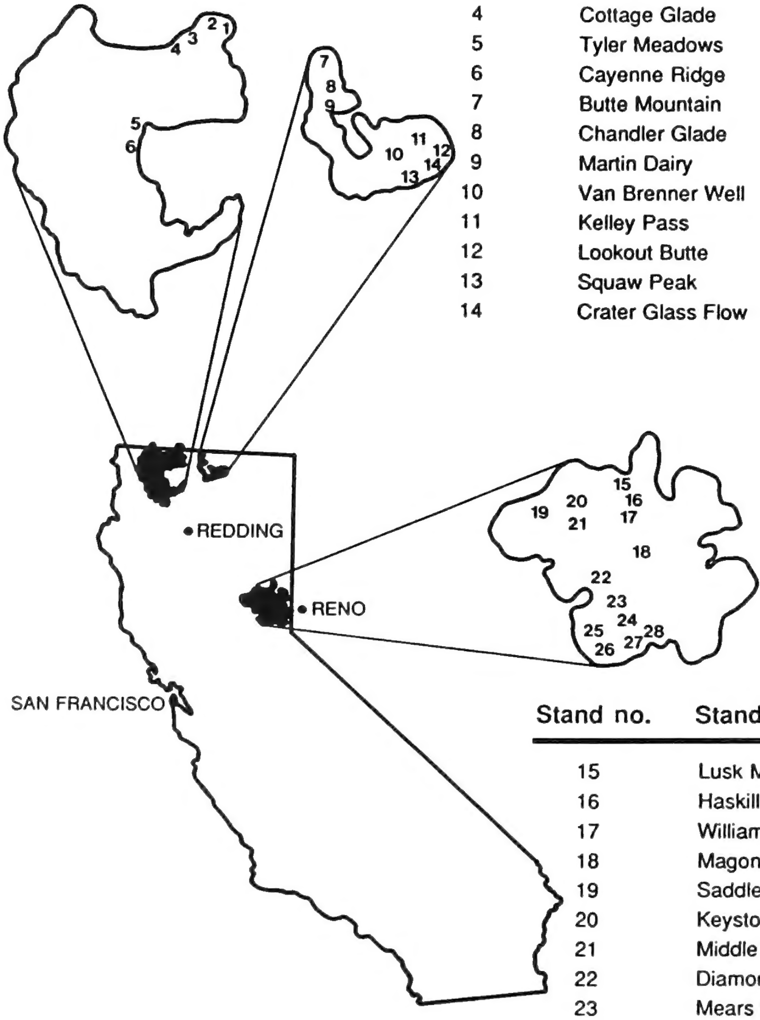
Twenty trees with one or more wounds were selected for study in each stand. In mixed-species stands, we selected 10 trees of each fir species whenever possible. Stand composition and stand damage in relation to tree species sometimes made this impossible. Trees were selected primarily near skid trails because most logging damage was concentrated there. Although wounded trees were not randomly selected, they were representative of tree size classes and sizes and types of logging damage found in the stands sampled.

Tree Dissection and Data Analysis

Before a tree was felled, species, diameter at breast height (d.b.h.)—4.5 feet—and crown class were recorded. In addition, the following information was noted: height from the groundline to the base of the wound, present wound width and length, and wound aspect on the tree. After a tree was felled and dissected, tree height and age, wound age, and original wound width and length were determined. Procedures for tree dissection and measurement and calculation of tree and decay volumes are described by Aho and others (1983b).

KLAMATH NATIONAL FOREST

Stand no.	Stand name	Ranger District	Legal description
1	Bull Gap	Oak Knoll	T40S, R1E, Sec. 22
2	E. Fork Grouse Creek	Oak Knoll	T40S, R1E, Sec. 20
3	Red Mountain	Oak Knoll	T41S, R1W, Sec. 5
4	Cottage Glade	Oak Knoll	T41S, R1W, Sec. 8
5	Tyler Meadows	Oak Knoll	T45N, R12W, Sec. 36
6	Cayenne Ridge	Scott River	T44N, R12W, Sec. 25
7	Butte Mountain	Goosenest	T46N, R3W, Sec. 4
8	Chandler Glade	Goosenest	T46N, R3W, Sec. 8
9	Martin Dairy	Goosenest	T46N, R3W, Sec. 27
10	Van Brenner Well	Goosenest	T44N, R2E, Sec. 30
11	Kelley Pass	Goosenest	T44N, R2E, Sec. 13
12	Lookout Butte	Goosenest	T44N, R3E, Sec. 16
13	Squaw Peak	Goosenest	T43N, R2E, Sec. 16
14	Crater Glass Flow	Goosenest	T44N, R3E, Sec. 32



TAHOE NATIONAL FOREST

Stand no.	Stand name	Ranger District	Legal description
15	Lusk Meadows	Downieville	T21N, R12E, Sec. 27
16	Haskill Peak	Downieville	T21N, R12E, Sec. 35
17	Williams Creek	Downieville	T20N, R12E, Sec. 14
18	Magonical Summit	Nevada City	T17N, R13E, Sec. 12
19	Saddleback	Downieville	T20N, R10E, Sec. 5
20	Keystone	Downieville	T19N, R11E, Sec. 2
21	Middle Waters	Downieville	T19N, R11E, Sec. 12
22	Diamond Road	Nevada City	T17N, R12E, Sec. 6
23	Mears Meadow	Nevada City	T16N, R12E, Sec. 12
24	Whiskey Hill	Foresthill	T15N, R12E, Sec. 1
25	Indian Creek	Foresthill	T15N, R12E, Sec. 4
26	Mosquito	Foresthill	T14N, R12E, Sec. 23
27	Deep Canyon	Foresthill	T15N, R13E, Sec. 28
28	French Meadows	Foresthill	T15N, R14E, Sec. 28

Figure 1—Locations of stands sampled in the Klamath and Tahoe National Forests.

Regression analysis was used to determine relations between amount of decay (either decay volume or percentage of total tree volume) and wound characteristics (size, age, height, condition, aspect) by tree species and by National Forest. Covariance analysis was used to detect significant ($P \leq 0.05$) differences in decay incidence between red and white firs on the two Forests.

Results

A total of 562 white and red firs with one or more wounds were sampled on the Klamath and Tahoe National Forests; however, 36 trees had wounds that occurred many years before the sampled stands were thinned. They were probably old mechanical or fire wounds not associated with thinning operations. These trees were not included in data tabulation or analyses to determine volume losses associated with commercial thinning. Decay losses associated with these old wounds were 3.1 and 7.1 percent of the cubic- and Scribner board-foot volumes, respectively, of the affected white and red fir trees.

As was also found in a similar study made in the Lassen National Forest in northern California (Aho and others 1983b), covariance analysis showed no statistically significant differences in decay associated with wounds between white and red firs sampled in either the Klamath or Tahoe Forests. Differences were significant, however, in decay associated with wounds on both species combined for the two National Forests. Therefore, both species were grouped by individual Forests for data tabulation and statistical analysis to determine wound characteristics related to decay volumes.

Basic data describing the size and age characteristics of the true firs damaged by logging in thinned stands in two National Forests are presented in table 1; 317 white firs and 209 red firs were sampled. Tree ages and sizes (d.b.h. and height) varied considerably for each species in each Forest, but variation in these characteristics between species was not great. On the average, the red firs were slightly older and had larger diameters than the white firs, whereas the white firs were slightly taller. Ranges of tree age and size in this study were similar to those of the sample studied on the Lassen National Forest (Aho and others 1983b). On the average, however, the trees in our study were older but did not differ much in diameter or height. Incidence of wounding, wound age, and amount of decay associated with sampled tree wounds for each Forest are presented in table 2.

Factors Influencing Decay Associated With Wounds

Past studies have indicated that certain characteristics of wounds may affect incidence of infection and amount of associated decay: wound age and size, condition (open or closed), height above the ground, and aspect. Because significant differences were not found between white and red firs in amount of decay associated with wounds, these species were grouped from each Forest to determine which wound characteristics were significantly related to associated cubic-foot decay volumes.

Table 1—Basic data for wounded white and red firs dissected in 28 thinned stands in the Klamath and Tahoe National Forests, California

National Forest and tree species	Trees	Age		D.b.h.		Height	
		Average	Range	Average	Range	Average	Range
	Number	*- - -Years - - -*		*- - -Inches - - -*		*- - -Feet - - -*	
Klamath:							
White fir	146	94	37-220	9.6	4.6-16.3	43	12-93
Red fir	112	107	53-182	9.9	5.8-18.4	42	13-77
Total or average	258	99	37-220	9.7	4.6-18.4	43	12-93
Tahoe:							
White fir	171	90	42-176	9.8	5.1-16.0	41	17-146
Red fir	97	101	58-223	10.0	5.4-18.7	37	17-78
Total or average	268	94	42-223	9.9	5.1-18.7	40	17-146

Table 2—Infection and decay data for wounded white and red fir in the Klamath and Tahoe National Forests, California

National Forest and tree species	Wound data				Tree data						
						Cubic-foot volume			Board-foot volume		
	Total trees	Total wounds	Wounds infected	Wound age	Total trees	Gross merchant-able	Decay	Range	Gross merchant-able	Decay	Range
	- - Number - -		*Percent*	*Yr*	*No.*	*Cubic feet*	*- - Percent - -*		*Board feet*	*- - Percent - -*	
Klamath:											
White fir	146	149	89	9	39	1,482.3	1.1	0-10.3	3,183	5.3	0.1-22.0
Red fir	112	120	90	10	33	1,141.5	1.4	0-11.0	2,458	6.2	.1-31.0
Both	258	269	90	9	72	2,623.8	1.2	0-11.0	5,641	5.7	.1-31.0
Tahoe:											
White fir	171	173	95	10	54	1,598.0	1.9	0-19.4	3,676	7.3	.2-47.0
Red fir	97	98	91	10	33	1,160.0	1.4	0-18.5	1,752	8.1	.1-26.0
Both	268	271	93	10	87	2,758.0	1.7	0-19.4	5,428	7.6	.1-47.0

Table 3—Infection and decay data by wound location for wounded white and red fir trees in the Klamath and Tahoe National Forests, California

Wound position[a]	Klamath National Forest				Tahoe National Forest			
			Cubic-foot volume				Cubic-foot volume	
	Total wounds	Wounds infected	Gross merchantable	Decay	Total wounds	Wounds infected	Gross merchantable	Decay
	Number	*Percent*	*Cubic feet*	*Percent*	*Number*	*Percent*	*Cubic feet*	*Percent*
Ground contact	98	94	1,156.7	1.8	127	97	1,562.0	2.8
Groundline to 4.5 ft	160	88	1,477.1	1.0	135	90	1,229.2	1.7
Above 4.5 ft	12	83	45.7	.4	9	89	80.0	3.7

[a] Indicates base of wound.

Neither wound aspect nor condition (open or closed) significantly influenced incidence of infection or amount of associated decay in the true firs in either Forest. Wound height had a significant ($P \leq 0.05$) effect on extent of decay in both Forests. Frequency of infection and amount of decay decreased as wound height increased in the Klamath sample (table 3). The results from the Tahoe sample differed. Wounds that originated either at the groundline or above 4.5 feet were more defective than those originating between the groundline and 4.5 feet. These results may have been influenced by the small sample of wounds above 4.5 feet.

The most important wound characteristics related to associated decay were wound age and original and present size (see appendix). Regression analysis showed that original wound area explained more variation in amount of decay than did present wound size. In Aho and others' (1983b) study, the opposite was found. Present wound size and age were used in regression analysis to develop equations that can be used to estimate cubic- and Scribner board-foot decay losses associated with thinning wounds on true firs in the Klamath and Tahoe National Forests. Although original wound size statistically was more closely related to decay, we used present wound area in these equations because (1) differences are small, (2) present wound size is easier to measure, and (3) we wanted the data to be comparable with the previous study (Aho and others 1983b). Cubic- and board-foot decay volumes that can be expected for wounds of various sizes and ages are given in tables 4 and 5.

Present wound area was calculated by multiplying wound length by width inside the callous tissue. Thus, only the open face of the wound was measured. The equations (and related statistics) used to derive tables 4 and 5 are in the appendix. The average decay volumes given in the tables are for young true firs less than 20 inches in d.b.h. Although amount of decay was correlated with size and age of wounds, the relation was highly variable. Coefficients of determination (R^2) or the variation in amount of decay that is explained by the variables (wound size and age) in the equations are low (see appendix). Accuracy of decay values predicted by the equations will often be low. Thus, they should be used only as general guidelines.

Table 4—Cubic volume of decay by wound age and wound area for second-growth white and red firs in the Tahoe and Klamath National Forests[a]

Wound age	Volume of decay when area of wound is:					
	0 ft²	1.0 ft²	2.0 ft²	3.0 ft²	4.0 ft²	5.0 ft²
Years	*Cubic feet*					
	TAHOE NATIONAL FOREST					
5	0.02	0.14	0.26	0.37	0.49	0.61
10	.09	.20	.32	.44	.55	.67
15	.15	.27	.39	.50	.62	.74
20	.22	.33	.45	.57	.68	.80
25	.28	.40	.51	.63	.75	.87
	KLAMATH NATIONAL FOREST					
5	.03	.12	.21	.30	.39	.49
10	.06	.15	.24	.34	.43	.52
15	.10	.19	.28	.37	.46	.56
20	.13	.22	.31	.41	.50	.60
25	.17	.26	.35	.44	.53	.63

[a] Wound size and age had a significant ($P \leq 0.05$) effect on amount of decay according to regression analysis.

Table 5—Scribner board-foot volume of decay by wound age and wound area in second-growth white and red firs in the Tahoe and Klamath National Forests[a]

Wound age	Volume of decay when area of wound is:					
	0 ft²	1.0 ft²	2.0 ft²	3.0 ft²	4.0 ft²	5.0 ft²
Years	*Board feet*					
	TAHOE NATIONAL FOREST					
5	2	4	5	6	8	9
10	3	5	6	7	9	10
15	5	6	7	9	10	11
20	6	7	9	10	11	13
25	7	8	10	11	13	14
	KLAMATH NATIONAL FOREST					
5	1	3	5	7	8	10
10	2	4	6	8	10	12
15	4	6	8	10	11	13
20	6	7	9	11	13	15
25	7	9	11	13	14	16

[a] Wound size and age had a significant ($P \leq 0.05$) effect on amount of decay according to regression analysis.

Discussion

Partial cutting, including commercial thinning, is commonly practiced in true fir stands in northern California. Stand entries with logging equipment can result in extensive damage to the residual trees. As many as 50 percent of the leave trees may be wounded by conventional logging procedures (Aho and others 1983b). A very high proportion of the wounds examined in the present study became infected by decay fungi (90 to 100 percent, depending on the National Forest). Board-foot-volume losses caused by decay associated with wounds are significant on the three Forests studied in northern California. Board-foot losses (for the wounded true firs sampled) were 5.7 percent on the Klamath, 7.6 percent on the Tahoe, and 12.8 percent on the Lassen National Forests. Decay losses were significantly different on the three Forests, which agrees with results from other studies. Amount of decay varies considerably from locality to locality for a given tree species. This may be due to differences in wound severity and frequency, site variables, or tree genetics. Our data indicate that true fir stands in California will experience substantial losses of volume from decay if wounding of residual trees is not minimized during the harvesting procedures.

A high proportion of wounds can be prevented through use of modified harvest preparation procedures and sale administration techniques (Aho and others 1983a, Filip and others 1983, Gravelle 1977, Johnson and others 1979, Meyer and others 1966). Application of the modified procedures has resulted in reduction of damage to residual trees by as much as 75 percent (Aho and others 1983a). It cannot be overstressed that wounding of residual trees must be minimized in true fir stands to prevent wound-induced decay that could nullify the benefits of commercial thinning.

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Appendix

Equations for Estimating Decay

The following multiple regression equations estimate cubic- and Scribner board-foot decay volumes when wound age and wound area are known. Wound area was computed by multiplying the present width and length of wounds at their longest and widest points within the callous tissue. Scribner board-foot volumes were calculated for trees 11.0 inches and larger in d.b.h. from a stump height of 6 inches to a merchantable-top-diameter inside bark of 6 inches. For cubic volume, the top diameter at breast height was 4 inches.

Table 4 was derived from equations 1 and 2 and table 5 from equations 3 and 4.

Cubic-foot volume equations:

Tahoe stands—

$$P_c = -0.0426 + 0.01294\,(A) + 0.1170\,(B). \quad (1)$$

$R^2 = 0.20 \quad S_{y.x} = 0.23 \quad N = 271$

Klamath stands—

$$P_c = -0.010 + 0.007\,(A) + 0.092\,(B). \quad (2)$$

$R^2 = 0.20 \quad S_{y.x} = 0.21 \quad N = 269$

Scribner board-foot volume equations:

Tahoe stands—

$$P_b = 0.915 + 0.248\,(A) + 1.360\,(B). \quad (3)$$

$R^2 = 0.19 \quad S_{y.x} = 3.98 \quad N = 87$

Klamath stands—

$$P_b = 0.510 + 0.300\,(A) + 1.840\,(B). \quad (4)$$

$R^2 = 0.19 \quad S_{y.x} = 5.47 \quad N = 72$

Where

P_c = cubic-foot decay volume,

P_b = board-foot decay volume,

A = wound age in years,

B = wound area in square feet,

R^2 = coefficient of determination or the amount of variation in decay that is explained by the variable in the equations,

$S_{y.x}$ = standard deviation about regression, and

N = sample size.

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Keywoods: Heartrot, logging damage, thinning, white fir, red fir.

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